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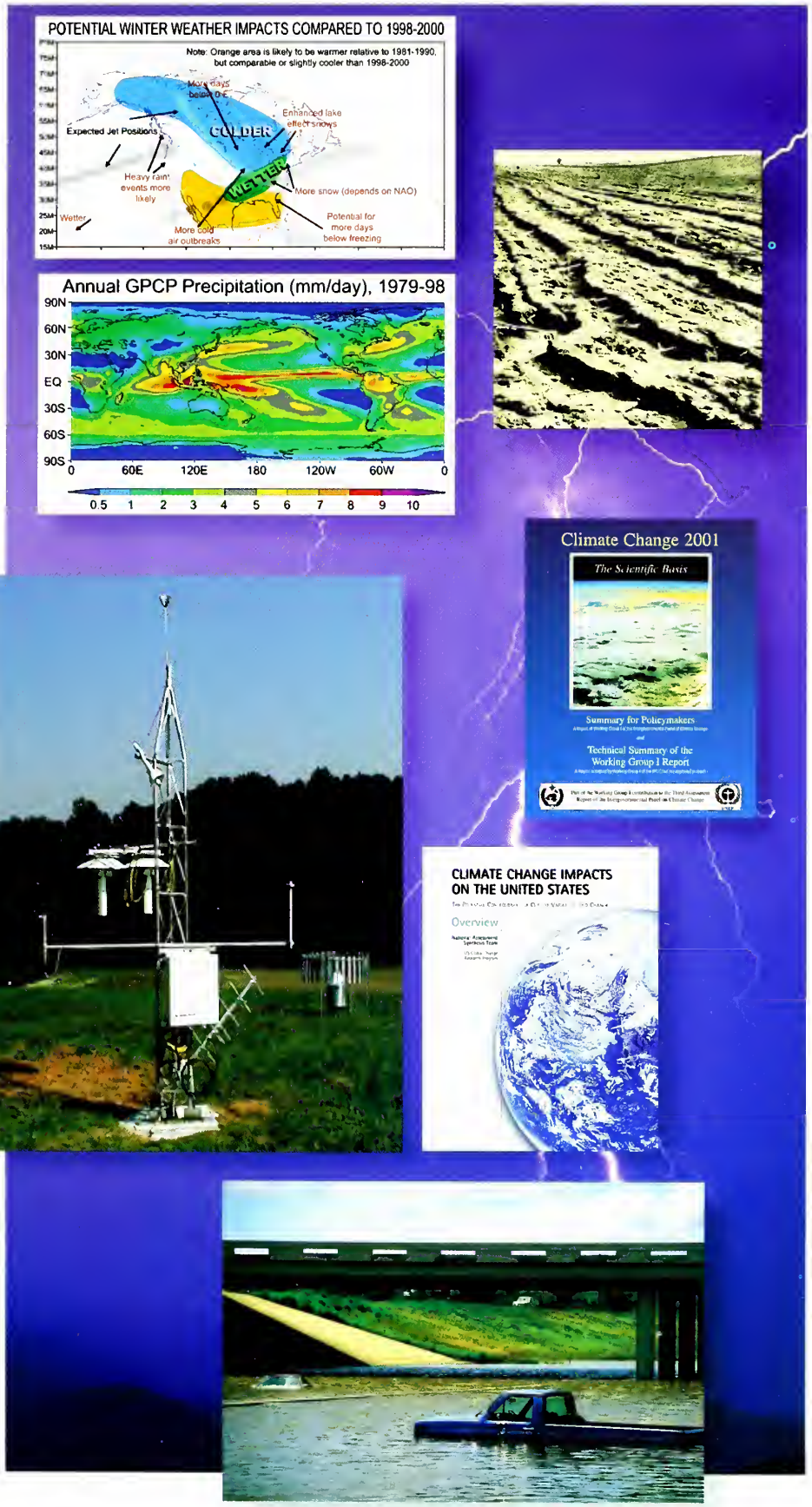

NOAA's Climate Observations and Services

- *Enabling Informed Decisions with Products and Services*
- *Transforming Data into Information*
- *Climate Services Foundations: The Observing System*

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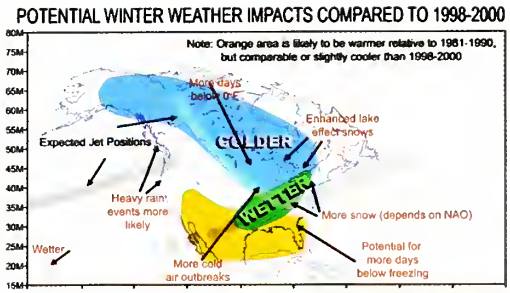

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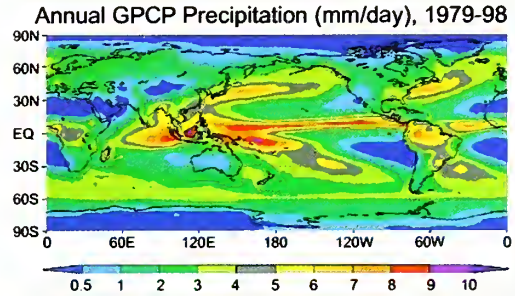

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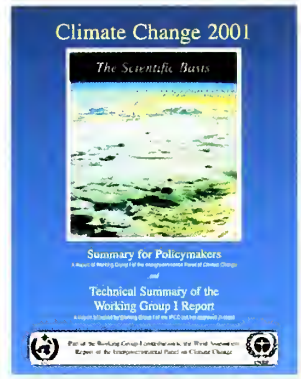

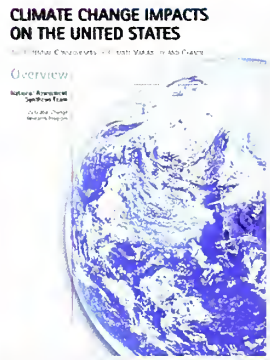

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FROM OUR FRONT COVER

A: U.S. Climate Outlook for Winter 2000-2001

B: Annual average precipitation from the Global Precipitation Climatology Project

C: Drought conditions during the Dust Bowl period

D: Climate Reference Network Station

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NOAA's Climate Observations and Services

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Monitoring and Observations
Research
Modeling
Services

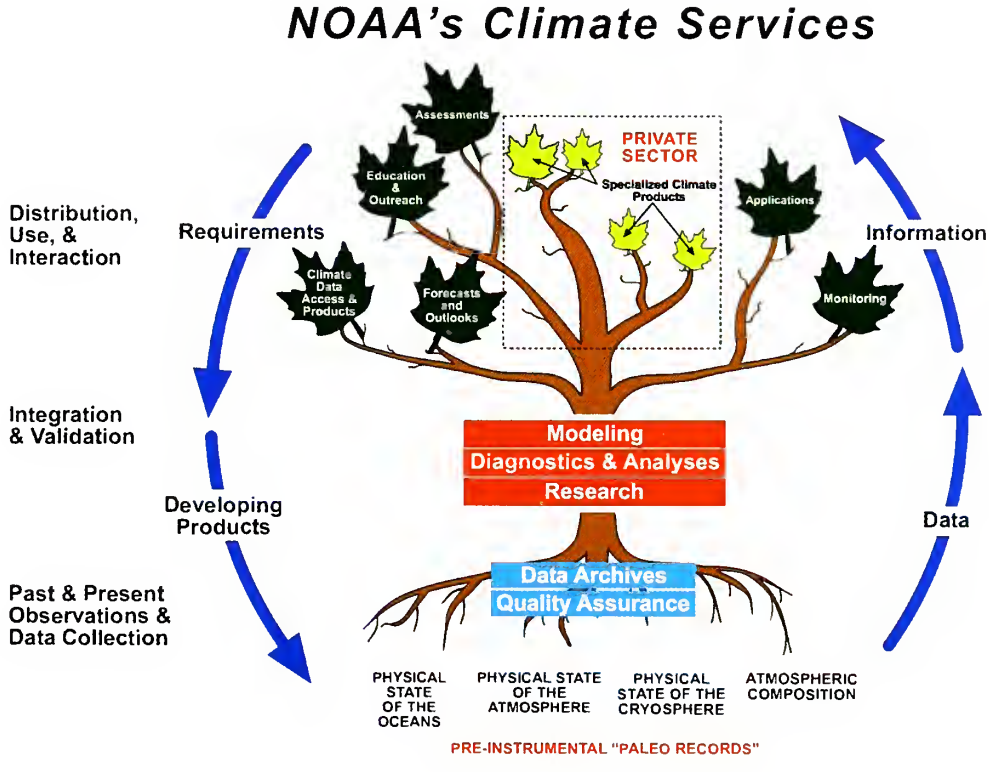
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Silver Spring, Maryland 20910 U.S.A.

1. Climate Services Program Overview

Climate change and variability have major ramifications for the nation, from the storms of next week to the drought of next season to the potential human-induced climate change over the coming century. Increasingly, NOAA is providing a range of climate services to users, from regional groups interested in climate impacts on water, energy or agriculture to international science assessment teams addressing global climate change. All interests are concerned with minimizing the risks of unusual climate conditions and maximizing its potential benefits. Climate information only acquires value through use. Simply put, the mission of NOAA's Climate Services is to provide people with climate information useful in making decisions.

This brochure describes these climate services, how and to whom the services will be provided, the operational NOAA-wide infrastructure required, and the necessary underlying research and analytical capabilities needed to assure highly credible information. It also describes the partnerships necessary to make it work and the management structure necessary to make it operate.

The structure for NOAA's Climate Services is illustrated in the tree figure. Leaves represent the products – climate forecasts and impacts assessments. Generation of these services requires a foundation of climate-quality



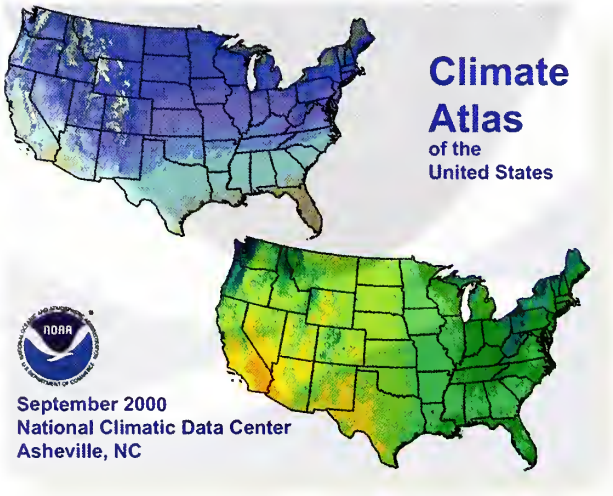
observations, taken both on the ground and from space. NOAA's climate services also require a base of focused research, and the modeling and analytical capabilities to turn these observational data into useful information products. At the same time, feedback from users translates into requirements to the observational, operational, and research programs for improving products, like leaves falling from the tree, fertilizing the soil and influencing the content of the observations.

2. Enabling Informed Decisions with Products and Service

Climate products and services are developed to meet the needs of individuals, communities, and industries impacted by climate. In many cases, the products and services are produced with the involvement of the end-users. Stakeholders and scientists express their requirements to NOAA management in constituent meetings and workshops. NOAA recognizes that there are climate products and services that are the domain of the private sector; NOAA provides services by establishing baselines upon which competitive industries can make decisions.

Climate Data Products

Information about climate is conveyed to users through statistical compilations of climate data in various atlases and other documents, often accessible through the world-wide web. Commercial and industrial sectors, public and private utilities, government, and the general public all require information about climate for planning and design. For example, planning for the peak capacity of energy power parks and transmission lines, water reservoirs, and storm-water runoff systems all require information related to expected climate normals and extremes during the lifetime of these systems. No bridge is built, no airplane is flown, and no home is built without designing to a set of climate operating characteristics. Hedging against extreme weather and climate events is a common practice, now routinely traded on the commodity exchanges with contracts drawn and settled based on climate normals. Information such as normal heating and cooling degree days is used by utilities to balance rates between cold and warm years. NOAA provides the official climate normals and climate information that are the basis for reducing the impact of extreme weather and climate events.



Assessments

Regional Assessments

To optimize the use of climate information, the emphasis must be on the pull for knowledge from regional users rather than on the push for science-based knowledge from providers. Responding to such demand requires focused research. Regional climate impact assessments are designed as integrated activities in order to describe climate variability, ecosystem complexities, and natural resource management institutions at the regional scale. The NOAA Regional Integrated Sciences and Assessments Program has found that users are much better served when research and services are responsive to local and regional concerns. Regional assessment programs involving universities, state and local governments, and NOAA researchers are underway in the Northwest, California, the Southwest, the intermountain West, and Florida. NOAA is also supporting assessments at the Regional Climate Centers. These have been central in bringing climate information to bear on regional concerns.

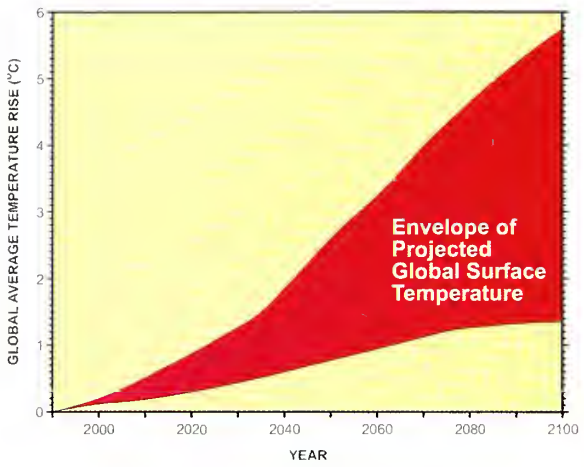
Impacts of climate variations (El Nino/Southern Oscillation, Pacific Decadal Oscillation) on the Pacific Northwest. The top panel shows how conditions over the North Pacific (specifically changes in sea surface temperature [SST], red colors) lead to slightly warmer, drier weather with less snow, less water in the rivers, less abundant salmon, and more difficulties for trees. The bottom panel shows how the opposite changes in SST have the opposite effects.

National Assessments

NOAA provides critical leadership, data, and research for national assessments. The recent assessment of the Potential Consequences of Climate Variability and Change was called for by a 1990 law and requested by the United States Global Climate Research Program. National assessments include research, analysis, and dialogue about critical environmental issues facing the nation. The assessments are built on a foundation of research and data and are extensively peer-reviewed by university, government and private sector scientists. They address impacts and options for adapting to an uncertain and variable climate.

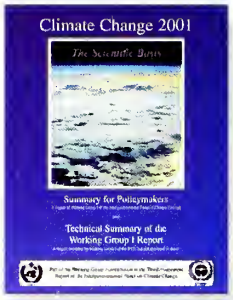
International Assessments

Climate issues today are global in nature, and NOAA leadership, science, and observations play a fundamental role in addressing these issues. Over



Simulated Climate Responses for a Range of Emission Scenarios

the past two decades the Intergovernmental Panel on Climate Change Assessments and the Stratospheric Ozone Assessments have been the scientific foundation of international policy on the topics of climate change and stratospheric ozone depletion. These assessments are considered to be the state of knowledge on the topics because they are based on the world's scientific literature, are carried out by leading international scientists, and are extensively peer-reviewed.



NOAA uses three-dimensional coupled ocean-atmosphere models to examine possible greenhouse gas-induced climate change over decades to several centuries and longer. This is done by specifying a range of potential future levels of greenhouse gases such as carbon dioxide and projecting how the model climate responds. These climate models are thus one tool to help distinguish between human-induced climate change and natural climate variability. Measurements of the current climate, historical observations, and glimpses of earth's climate during the ice ages and other past climates all provide opportunities to test climate models. Through research on climate models and observations, NOAA scientists continue to evaluate and refine the climate models that will be needed to help answer critical policy-relevant questions about global climate change and its consequences.

State of the Climate: Monitoring

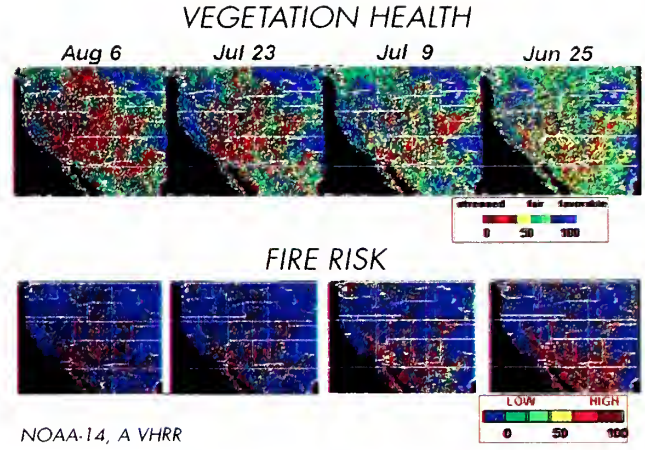
NOAA provides regularly scheduled releases about the changing state of the climate. This information addresses all aspects of climate, ranging from drought and heat waves to stratospheric ozone concentrations. Information is provided in the context of past events and trends and is often accompanied by projections and outlooks. Major releases occur annually and seasonally, with monthly updates and more frequent releases during extreme events.

NOAA collects and provides to users daily and monthly data, time series, and maps for various climate parameters, such as precipitation, temperature, snow cover, and degree days for the United States and other parts of the world. In addition, NOAA compiles data on atmospheric and oceanic conditions, including El Niño/Southern Oscillation (ENSO); other climate patterns such as the North Atlantic and Pacific Decadal Oscillations; and stratospheric ozone and temperature.

Reviews of current weather and climate information are also issued on a routine basis. For example, NOAA, together with the U.S. Department of

Agriculture and the National Drought Mitigation Center in Lincoln, Nebraska, issues a weekly drought assessment called the U.S. Drought Monitor.

A variety of analysis and visualization tools are available online, allowing users to view weather and climate information, either in near real time or for historical events. For instance, a web-based "map room" displays atmospheric and oceanic fields updated on a daily basis.



Drought monitoring and fire danger index showing large area of extreme vegetation stress in the Western U.S. 2000.

Applications

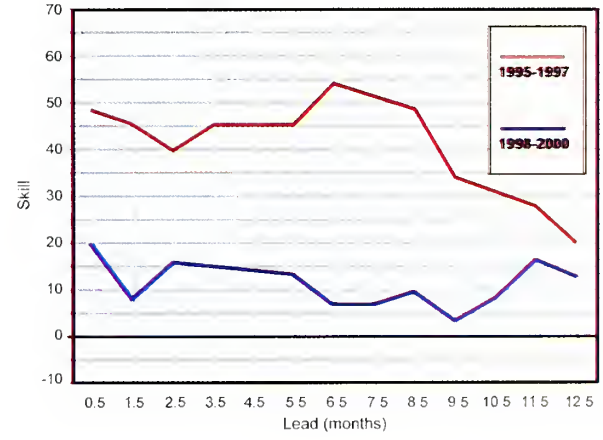
Over the years NOAA has developed a number of products that are now provided on a routine basis. These include indices to monitor droughts, wetness, various states of the general circulation, heat and cold stress, storm intensity, and ground conditions like its vegetative state, snow cover, and frost conditions. Applications for these products by the private sector and the public are extensive. NOAA works closely with its users to ensure that these products are effective for many users. Examples include work with scientific and engineering societies like the American Society for Heating, Refrigeration, and Air Conditioning for Engineers or representative groups like the Western Governors' Drought Monitoring Task Force and the American Home Builders Association.

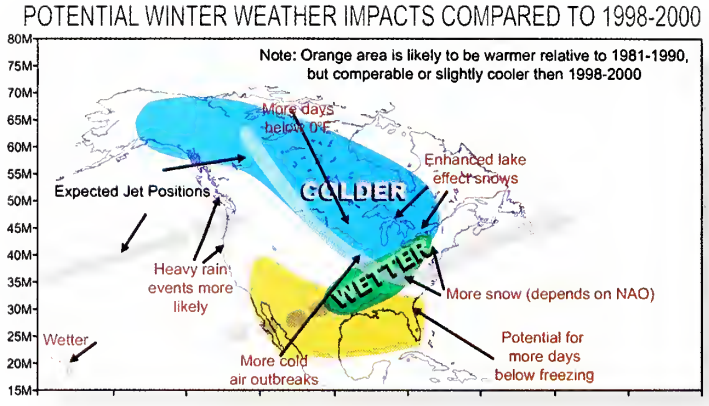
But applications activities are not only about data. Climate applications require that institutional arrangements be analyzed for their capacity to use climate information, that information use be evaluated for its effectiveness, and that a trust-building dialogue among the research, operational and decision-making communities be developed so that uncertainties are recognized and risks addressed.

Forecasts and Outlooks

NOAA's forecast products consist of operational predictions of climate variability and scenarios for future climate. The operational predictions cover time scales from a week to seasons, extending into the future as far as technically feasible, and cover the land, ocean, and atmosphere, extending into the stratosphere. Recent breakthroughs in climate prediction techniques have led to statistical and dynamical ENSO forecasts with record-breaking skill and outlooks for hurricane season activity. One of the breakthroughs is the use of model ensembles. Using this technique, several model predictions are made from the same basic state, but the initial state in each

Improvement of predictive skill for cold season temperature forecast, relative to chance

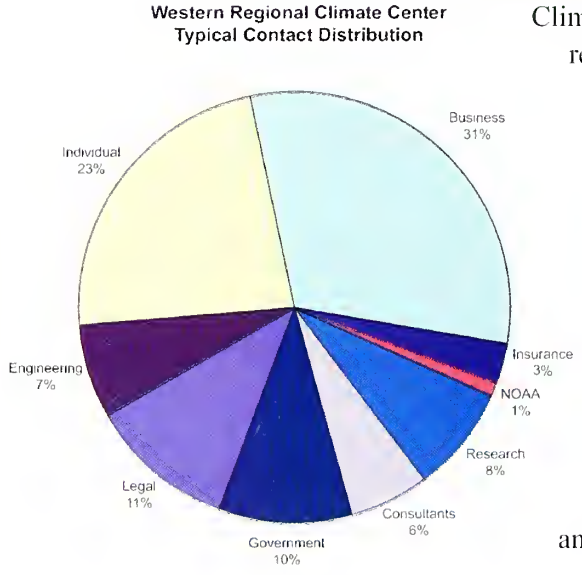




member of the ensemble is modificd very slightly at the start of the computer simulation. The result is a number of forecasts whose end states may be very different in some cases. This provides a measure of confidence in the resultant forecast patterns.

These advances enable NOAA to move toward a seamless suite of products, all dcriving probability measures from the ensemble results. Recently, the 6-10 day, week 2, and excessive heat forecasts have been converted to this approach. NOAA has also gained new understanding of predictable and unpredictable phenomena contributing to winter variability. Predictable phenomena include intraseasonal disturbances in the tropics that strongly impact North America. Insight into these is beginning to be incorporated into 6-10 day and week 2 forecasts, as well as the popular Threats Assessment. These provide emergency managers, planners, forecasters and the public up to two weeks advance notice of potential threats related to extremes of temperature, wind, precipitation, soil moisture and the risk of wildfire. Advances in forecast methodology integrate existing short-and long-range forecasts, using state-of-the-art science and technology in their formulation. As a companion product to the weekly Drought Monitor, NOAA now disseminates a seasonal Drought Outlook on a monthly basis. NOAA also issues several special outlooks, such as probabilities of exceedances for heating and cooling degree days and a forecast for daily ultraviolet (UV) radiation index.

Education and Outreach



Climate variability affects decisions that people make on regional and local levels, from droughts and floods to heat waves and cold snaps. For example, NOAA's southwest regional assessment, which is considering historical droughts in aquifer recharge, has now become a major point of attention by the Arizona Governor's Planning Commission in revising the 1980 Groundwater Management Act. In the Pacific Northwest, water managers have come to the table with scientists to consider the agricultural, hydropower and environmental implications of a sustained drought. An important lesson here is that climate products are of minimal use unless they are delivered in a regional context and in a form that people can use. NOAA uses an array of resources to produce climate information for

different regions. These include regional consortia of local university and government experts, along with the professional meteorologists, hydrologists, and climatologists of the local weather and river forecast offices. NOAA is actively developing training materials in climate services for its operational workforce. Much of this web-based and tele-training material will be provided to NOAA's partners in the external community. Further, NOAA provides teaching aids covering climate change and ozone layer depletion to schools across the country. By engaging its customer groups at all levels in continuing dialogue, NOAA is better able to develop customer requirements.

Private Sector Products and Services

NOAA works closely with its private sector partners to ensure that the data and information delivered are readily understood and can be used to develop value-added tailored products and services for business and industry. This may take the form of constituent meetings, joint workshops or forums. The private sector has varied interests. For example, the weather risk industry uses many of the products and data NOAA provides to hedge against unusual weather and climate conditions. Consulting climatologists make extensive use of NOAA's data and information to address specific issues related to various business applications like marketing, insurance claims, building design efficiencies, transportation needs, and agribusiness issues.

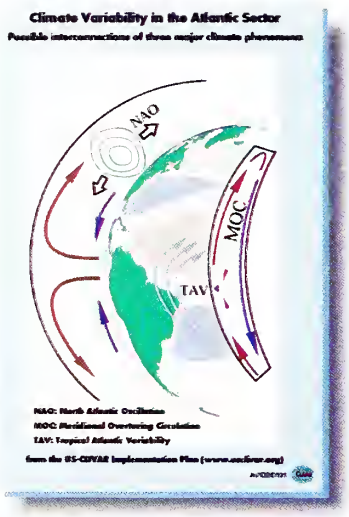
3. Transforming Data into Information

Research, analysis, and computer modeling provide the means to reveal connections between oceans, land, and atmosphere, to determine the physical and biological dimensions of such connections, and to reproduce those connections with computer modeling. Information from this research must then reach communities who can use it in decision-making. Outreach to provide information is important, as is involving users in the research processes itself, so that data collected and research conducted will have a positive impact on society. There must be feedback between those who collect and archive data and those who would put that data to use.

Research

Climate Variability

Scientists have identified several recurring large-scale patterns of variability (such as the El Niño-Southern Oscillation or ENSO) that interact to influence our climate on a regional scale. In addition to the ENSO phenomenon, recent evidence has pointed to several other sources of climate variability over the



U.S., including the North Atlantic (or Arctic) Oscillation, Tropical Atlantic Variability, the Pacific Decadal Oscillation, and the Pan-American monsoons. Just as the investment in ENSO research over the past decade led to our current, somewhat limited, predictive capability for seasonal climate, an accelerated research agenda focusing on other dominant patterns holds promise for improving climate predictions. NOAA is investing in the US Climate Variability and Predictability (CLIVAR) program to observe, model and understand natural variability on seasonal-to-decadal time scales and to assess the predictability of such climate variability. The ultimate goal of NOAA's focus is to develop skillful predictions of climate variability on intraseasonal-to-interdecadal time scales and regional space scales for optimal use in resource planning. The program is designed to understand global climate variability; to determine the spatial and temporal extent to which this variability is predictable, to develop the observational, theoretical, and computational means to predict variability; and to make enhanced predictions, where feasible.

Water Cycle

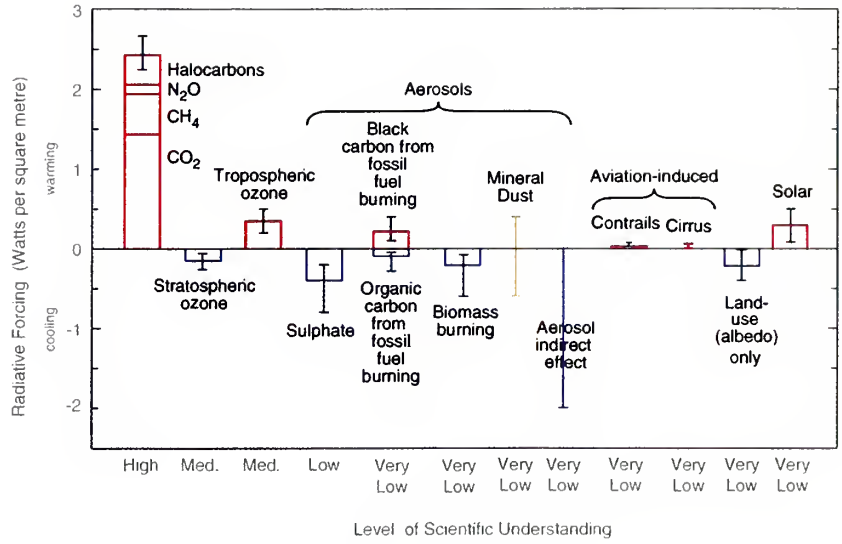
The global water cycle is one of the most significant aspects of climate research and services because water is a critical driver for most climate processes and it determines the availability of water for effective natural resource management. Many global water cycle issues are addressed by the Global Energy and Water Cycle Experiment (GEWEX) within the World Climate Research Program. In addition to supporting the Global Precipitation Climatology Project and the International Satellite Cloud Climatology Project, the specific aspects of GEWEX addressed by NOAA water cycle activities relate to the water/energy exchange processes involved in the coupling of the atmosphere and the land surface (e.g., precipitation, evaporation and runoff). The present emphasis is on determining the sources and limits of predictability of precipitation over North America, with emphasis on time scales ranging up to seasonal-to-interannual. The objectives of the GEWEX Americas Prediction Project include examining: (1) land memory processes (soil moisture, snow, vegetation); (2) cold-season precipitation, especially relating to orography in the western U.S.; (3) warm season precipitation, especially relating to the Southwest Monsoon; (4) predictability of the hydrological cycle and development of an end-to-end prediction system, including transferability of models between regions; (5) applications to water resource management. Further, studies within the OAR laboratories are actively exploring how to address the daunting issue of ground water, including the formulation of soil moisture in models and the overall water balance on watershed scales. Airborne systems to measure the rate of exchange between the air and the surface of water vapor are now in regular use, to address the issue of how best to describe evaporation rates over complex terrain, both regarding vegetation and topography. The same airborne systems are being used

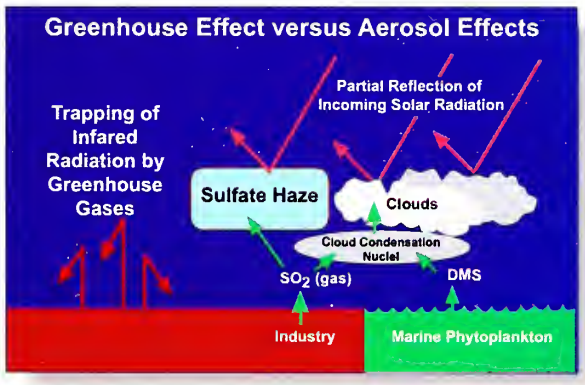
to refine understanding of evaporation rates from the oceans.

Atmospheric Chemistry and Aerosols

NOAA's Atmospheric Chemistry program seeks to understand the chemical and radiative processes associated with trace chemicals in the atmosphere. The major coupling mechanism between incoming solar radiation – visible, ultraviolet, and infrared – and the global atmosphere is via the atmospheric trace gases, aerosols (i.e. airborne fine particles), and clouds. Therefore, characterization of that coupling lies at the heart of the prediction of much of the variability and changes in the global system. Reducing the uncertainties in climate forcing agents is identified as having one of the highest priorities for the coming decade. Three main radiative-forcing endeavors are being maintained: understanding changes in the ozone layer over the coming decade; quantifying the trends and source/sinks of long-lived greenhouse gases; and characterizing the properties, distributions, and fundamental processes that control the shorter-lived radiatively- and chemically-active species, both gases and aerosols. This better quantification of the agents that cause climate change, as well as the emissions and removals of these species, will yield more accurate projections of future atmospheric composition and hence climate. NOAA interfaces these studies with measurements of precipitation chemistry, both nationally and worldwide, as well as measurements of visible and ultraviolet radiation.

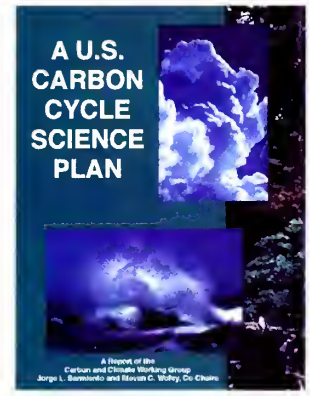
The global mean radiative forcing of the climate system for the year 2000, relative to 1750





Carbon Cycle

NOAA's Carbon Cycle program seeks to improve our ability to predict the fate of anthropogenic carbon dioxide (CO_2) and future atmospheric CO_2 concentrations using a combination of atmospheric and oceanic global observations, process-oriented field studies and modeling. One of the most noticeable changes NOAA has measured in the Earth's atmosphere over the past 50 years is the consistent increase in carbon dioxide concentration.



Carbon dioxide is intrinsically linked to climate, because it acts to trap heat in the atmosphere, thus affecting both temperature and precipitation patterns. A major uncertainty in climate prediction is knowing how the cycling of carbon between land, ocean and atmosphere will change as climate and land use patterns change. Currently, the Earth system absorbs about half of the excess atmospheric carbon dioxide released by human activities. Some of the CO_2 is absorbed into the ocean, and some is absorbed by plants and soils on land. There is increasing interest in discovering how to actively manage our resources such as land, coastal and open ocean environments to reduce the amount of carbon dioxide in the atmosphere. By observing, studying, and modeling carbon processes in the atmosphere, the ocean and on land in an integrated way, NOAA will be better able to predict future atmospheric carbon dioxide concentrations, and, therefore, future climate patterns. To this end, NOAA is a leading participant in the international programs to address the issue of terrestrial carbon sequestration and is actively exploring how to improve formulations describing the transfer of carbon dioxide from the air to the ocean.

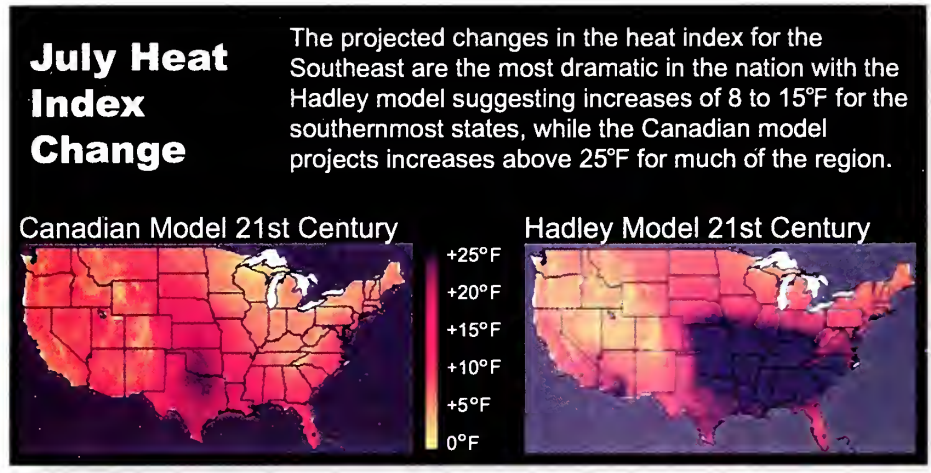
Climate and Society

NOAA has expanded the breadth of its climate program to improve our understanding of how social and economic systems are currently influenced by fluctuations in short-term climate (seasons to years), and how human behavior can be affected based on information about variability in the climate system. By illuminating institutional, economic, and cultural behavior, social science research on climate-human interactions plays a critical role in determining how humans currently prepare for and respond to climate variability and how analysis of these interactions could improve human welfare. The emphasis on shorter time scales allows the program to pursue the affinity between these time scales and the time horizon on which many climate-sensitive decisions are made. Moreover, lessons learned from analyzing how humans currently adjust to climate may have important implications for longer-term adaptation in the face of climate change. An area of active development at this time is related to the effects on human health from climate variability. This includes mortality increases related to climate extremes, e.g. heat waves, and incidences of vector-borne (from insects) diseases.

Modeling

Every day countless environmental related decisions are made by energy companies, commodities markets, agribusiness, insurance companies, water resource managers, and local, state, and federal agencies. To make wise decisions they need information about what is going to happen tomorrow, next week, the next season, the next year, and out to centuries into the future. Numerical models are the keys to providing this information. The nation has come to expect forecasts out to a week or so, resulting

from weather forecasting models. For longer-range forecasts, models are used to predict both seasonal-to-interannual climate variability and climate change over decades to centuries. To assure continued improvement of these climate forecasts, NOAA has a strong program that involves both universities and internal efforts.



Operational Modeling

NOAA maintains a full suite of operational global and regional atmospheric models, ocean models, a sea ice model and a land surface model for global and regional climate applications. Operational climate forecasts for seasonal-to-interannual time scales are supported with a coupled atmosphere-ocean model and employ ensemble techniques to account for varying probability density functions for different climatic regimes. NOAA is extending these model ensemble techniques to forecast periods beyond the purely deterministic short-term weather time frame (5 to 7 days) to situations where boundary or external conditions (e.g. the tropics for extratropical forecasts) play an ever-increasing role compared to initial conditions (the short-term weather integration).

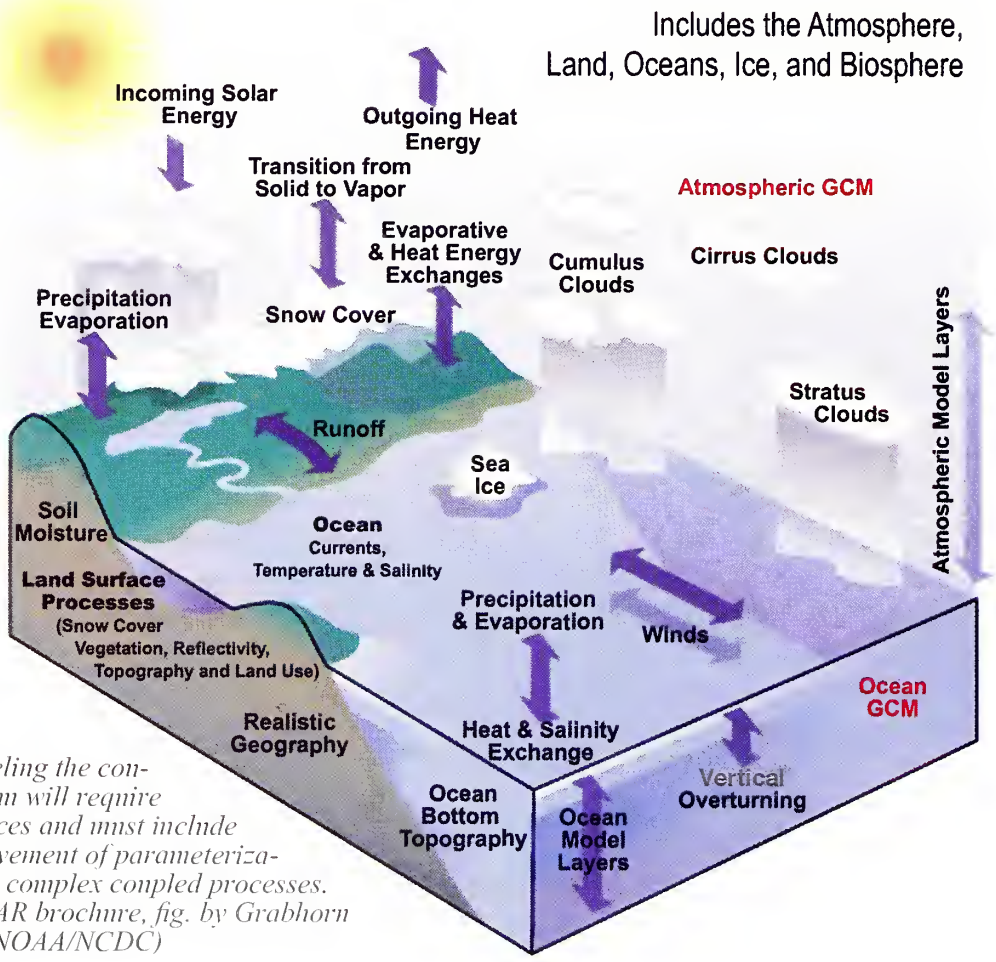
Climate Change Modeling

NOAA has a long history in the development of climate, global ocean, and atmospheric models. Its research advances have been key to the development of improved operational weather, climate, and hurricane forecasts and have been key in our improved understanding of the causes of global warming. NOAA continues strong efforts to develop the next generation of climate models required to understand the impact of climate change on climate variability and extreme weather events on local scales and to transition modeling improvements into operational forecasting.

Experimental Prediction

NOAA supports a program of seven Applied Research Centers. These are NOAA and academic research programs of research, development, and experimental applications intended to improve the national capability to predict the Earth's climate system. NOAA has also established an International Research Institute for Climate Prediction, whose task is to accelerate the ability of societies worldwide to cope with climate fluctuations, especially those that

Modeling the Climate System



Successfully modeling the coupled climate system will require significant resources and must include testing and improvement of parameterizations of numerous complex coupled processes. (From U.S. CLIVAR brochure, fig. by Grabhorn Studio, based on NOAA/NCDC)

have devastating impacts on humans and the environment. This research on climate prediction is strongly coupled with applications research.

Diagnostics and Analysis

Modeling and prediction of climate is built on the analysis of how climate has changed in the past, and in particular the identification, or diagnosis, of the nature of changes in the climate system. NOAA has strong breadth and experience in climate diagnostics, using data and theory about climate to describe what has happened. Diagnostic studies link basic observational and theoretical research on climate processes to improvements in operational climate predictions and, ultimately, to the development of new climate products. For example, the analysis of tropical Pacific sea level, ocean and air temperature, and barometric pressure was instrumental in diagnosing the processes involved in El Niño. Some specific aspects of diagnostics and analysis include data set development, model-based reanalysis, and trend analysis.

Data Set Development

To better understand, predict and assess the climate, data and information are aggregated in time and space. Data set development often includes integrating in situ and satellite observations for a specific area of interest to produce a reliable long-term climate record. The archives of NOAA and other agencies and countries are explored to assemble the most comprehensive collection of data for a particular topic. Detailed information about the observing systems and uncertainties related to the data are essential to the data set development effort. Examples include ocean marine, upper air, sub-surface ocean, paleoclimatic, and precipitation data sets. Important considerations in the development of any data set are the intended users and the type of access expected. NOAA focuses on providing appropriate data set structures for the intended use of the data.

Model Reanalysis

The climate record is an immensely valuable asset. In its ideal, climate variables such as temperature and precipitation would be known from consistent measurements everywhere and as far back in time as needed. In reality, models used to forecast climate use the best available observations to generate these climate variables in the past. This is model reanalysis, and it has become a very valuable climate service product. In this hindcast mode, comprehensive data can be gathered and a consistent state-of-the-art model can be used to generate high-resolution data related to weather conditions during past decades. These data can then be analyzed, archived, and distributed for use. Applications of these data range from storm climatologies to information on intercontinental transport of atmospheric constituents.

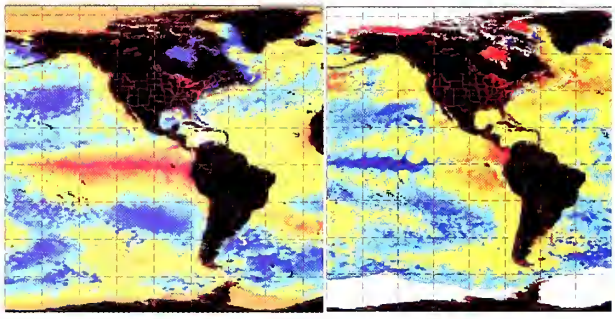
Trend Analysis

To develop information about changes and variations in climate on decade-to-multi-century time scales, NOAA scientists use data collected from observing systems, climate-related data collected by other agencies, data exchanged internationally, as well as pre-instrumental paleoclimate records. Careful attention is given to the time-dependent biases that often accompany data collected over long periods of time. These biases can be as large as, or even larger than the actual variations and trends in climate. Because of this, substantial research is focused on removing biases to uncover the true climate signal. There are few benchmark measurements that can be used to discern changes without concern for changes in spatial sampling, temporal sampling, instrument changes, instrument degradation, and the local environment affecting the measurements.

4. Climate Services Foundations: The Observing System

Observations are the foundation of climate services, although much of the data used in climate services have been collected for other purposes. Both in situ and satellite observations are necessary to address climate needs. Data must be collected from the important elements of the full climate system for a comprehensive view and to allow optimal monitoring, prediction, and services. Archiving of the data is critical, as many of the important uses of the data will be years into the future.

Sea Surface Temperature Anomalies

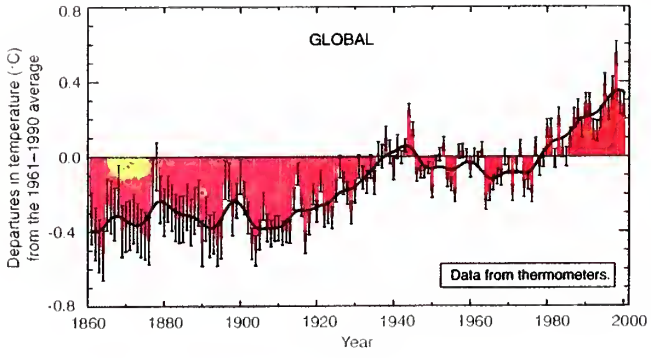


El Nino - February 1998 La Nina - August 1998

Physical State of the Oceans

NOAA monitors the state of the oceans through various systems including satellites, ocean ships, moored and drifting buoys, ocean profiling floats, ocean reference stations, and hydrographic lines from ocean research ships. The data from these observing systems include elements such as sea level, ocean temperature and salinity, ocean wave heights, tides, and ocean circulation. These data are routinely measured at least several times each day. The spatial coverage is near global for fields like ocean temperature and sea level where satellite data supplement surface-based measurements, but less than global for other elements that rely on surface-based observing systems. Much of the ocean surface and sub-surface data from ground-based observing systems are derived from international exchange agreements set up by the World Meteorological Organization and other agreements. Using these basic measurements NOAA derives information about the fluxes of heat, momentum, and energy between the ocean and the atmosphere.

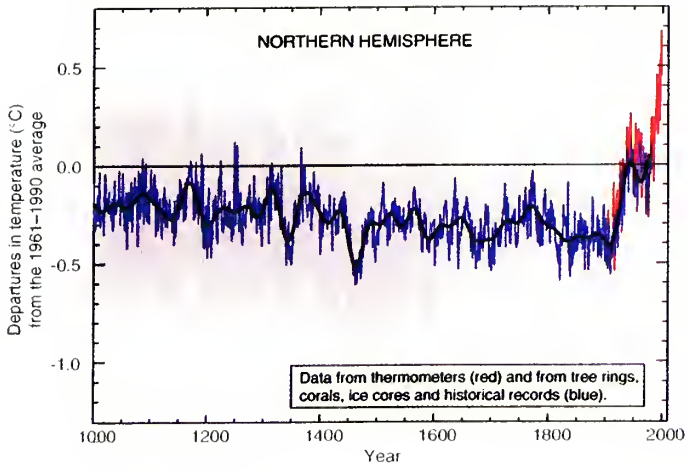
Variations of the Earth's surface temperature for: The Past 140 Years



Physical State of the Atmosphere

NOAA monitors the state of the atmosphere through a complement of space-based and surface-based observations. Vertical profiles of temperature, pressure, humidity and winds through the atmosphere are obtained twice a day from weather balloons launched simultaneously around the world and internationally exchanged for research. Traditional surface-related climate variables like temperature, precipitation,

Variations of the Earth's surface temperature for: The Past 1000 Years



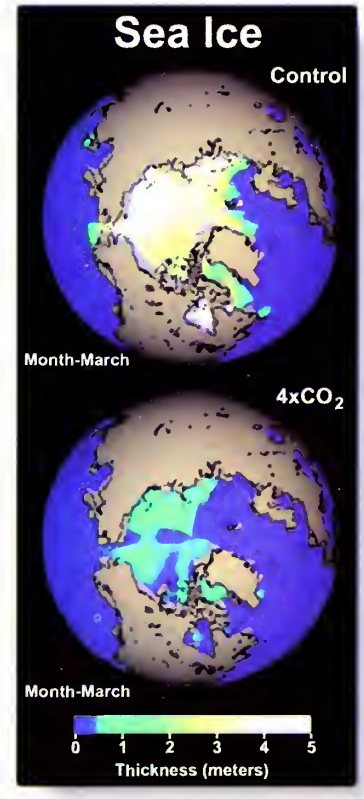
humidity, and pressure are derived primarily from surface-based observations, but are supplemented with satellite measurements. Since satellites measure radiant energy from the earth-atmosphere system, climate variables must be derived using various complex algorithms. Variables include cloud amount, reflected energy, radiated energy, precipitation, and many others. Radar data within the U.S. can be used along with traditional surface-based precipitation measurements to derive minute-by-minute fields of precipitation, with far higher resolution than would be possible using rain gauge data alone. Precipitation measurements over the oceans are derived primarily from satellite data. For global coverage NOAA relies heavily on surface-based observations from other countries. The World Meteorological Organization plays a critical role in helping to establish and facilitate data exchange policies.

Physical State of the Land Surface and Cryosphere

Satellites and surfaee-based observing systems are used to monitor the physical state of the earth's surface, including the cryosphere (snow and ice-covered surfaees). NOAA operates three basic networks that provide information about the climate at the Earth's surface: one is operational, one is under consideration for modernization, and one is being deployed.

The Automated Surface Observing System (ASOS) replaced the manual observing system that was in place at all airport locations prior to the 1980s. One thousand ASOS stations provide information on weather conditions in and around urban areas. The data are widely used by business and industry.

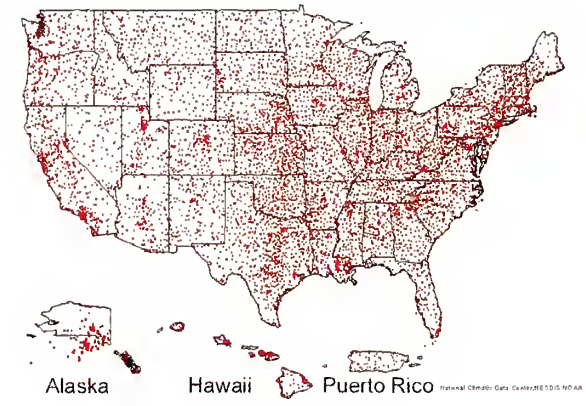
The Cooperative Observer (CO-OP) Network consists of over 11,000 sites, most equipped with both temperature and precipitation sensors to provide the dense temperature and precipitation observations necessary to track climate variability at regional and local levels. The observers are volunteers who take daily readings and submit their data to NOAA on a monthly basis. NOAA is proposing to modernize this network with an



automated system that would provide hourly access to temperature and precipitation readings from approximately 8,000 sites. The high-density data will improve NOAA's ability to monitor climate anomalies in real time. In addition, 1,000 sites in agriculturally-sensitive areas will be further equipped with soil moisture, temperature, and evaporation sensors to monitor drought and the water cycle. The network will also provide a new source of real-time information for exploitation by the private sector.

The Climate Reference Network (CRN) will utilize approximately 250 sites equipped with a suite of instruments to provide highly-accurate, long-term tracking of continental scale climate change. The CRN will provide continuous, highly-accurate near-complete measurements of the surface energy balance that meet the exacting requirements of the meteorological and hydrological research community. The daily data will also provide the baseline measurements for calibration of the CO-OP Network and other observing systems. CRN sites will be carefully selected to best represent the climate regions of the United States and minimize the potential for human-related modifications to the site. Site selection for the modernized CO-OP Network will account for and exploit planned CRN sites.

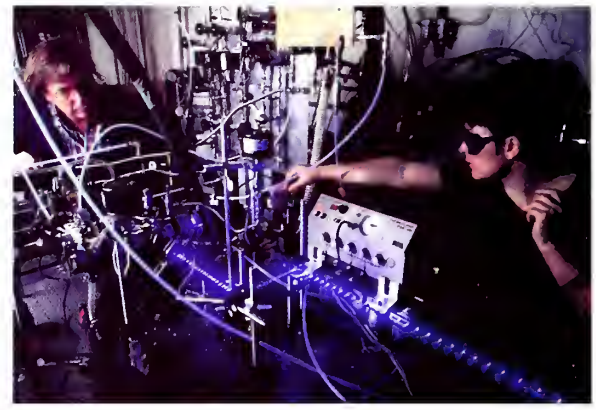
UNITED STATES COOPERATIVE OBSERVER NETWORK



As part of the international Baseline Surface Radiation Network, NOAA also operates a surface radiation network that includes measurements of long- and short-wave components of surface radiation for determining the surface radiational heating. These data provide a reference baseline for satellite estimates of surface radiation. NOAA measures the entire radiation balance at the surface at many sites, and couples these measurements with convective and conductive transfer measurements so that all components of the surface energy balance are described accurately.

Geostationary and polar orbiting satellites, operated by NOAA and other agencies, provide data on sea ice and extent of snow cover. Information about the reflectivity of snow, the type of sea-ice, and other data related to the state of the cryosphere are retrieved from satellite observations using a variety of algorithms. Surface-based measurements are used for variables such as snow depth, snowfall, and snow water equivalent. In the United States and other countries these data have a time resolution of at least once per day.

Atmospheric Composition



NOAA researchers make laboratory measurements to determine the properties and lifetimes of atmospheric gases that influence the radiation budget.

NOAA conducts sustained regular observations and research related to source and sink strengths, trends and global distributions of atmospheric constituents that are capable of forcing change in the climate of the earth through modification of the atmospheric radiative environment and the chemistry of precipitation. This includes those that may cause depletion of the global ozone layer and those that affect baseline air quality. NOAA laboratories accomplish this mission primarily through long-term measurements of key atmospheric species at sites spanning the globe, including four fully equipped Baseline Observatories and the Atmospheric Integrated Research Monitoring Network in continental U.S., in association with the Global Atmospherc Watch of the World Meteorological Organization. Key species and properties include carbon dioxide, carbon monoxide, methane, nitrous oxide, surface and stratospheric ozone, chlorofluorocarbons and related compounds, hydrocarbons, sulfur gases, aerosols, and infrared, visible, and ultraviolet radiation. In many cases, NOAA helps maintain the central calibration standards. Observations from the SBUV (Solar Backscattered Ultra Violet) instrument on NOAA polar orbiting satellites contribute to this mission by providing a global view of the total ozone and vertical profiles of ozone from the surface into the stratosphere. From the measurement of changes in the chemical content of precipitation, the trends in the atmospheric composition can be usefully inferred, because precipitation is an efficient scavenger of water-soluble chemicals that may be difficult to monitor directly.

Pre-Instrumental Paleoclimate Records

Climate history prior to direct measurements is derived from a host of data sources. These include tree rings, corals, ice cores, lake and ocean sediments, pollen data, historical documents, and other sources. NOAA supports efforts to gather and assemble these data that provide information about changes and variations of temperature, precipitation, drought, and other important climate characteristics across the globe. NOAA emphasizes extreme events and data that can resolve seasonal to inter-annual climate variability and change.

Data Archives

All of the data collected by NOAA's operational observing systems, including internationally exchanged data and those data important for research experiments, are archived for distribution and use. NOAA applies various levels of quality control on the data and develops information about the data and observing systems from which they are derived. Increasingly, these data are being made available through the Internet. NOAA archives contain nearly

one petabyte of data, equivalent to the data stored in about 100,000 modern personal computers.

5. Partnerships

NOAA maintains partnerships with universities, private industry, other US agencies, nations, and international bodies to observe the climate, to gather information from the data, and to make and assess predictions of climate.

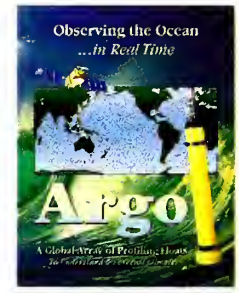
Universities are important links in the climate research and information dissemination network for the United States. University researchers develop knowledge about climate dynamics and other physical processes essential to improving global climate models. University researchers are also important for bringing output from such models to the regional scale in order to attain better resolution about how global changes will impact regions and relevant sector. Network-building efforts underway in the form of regional integrated sciences and assessments will eventually include all regions of the United States. NOAA maintains these close partnerships with universities in the process of ongoing assessments of the impacts of climate change and variability on the United States. Universities are also central in the development of ocean observing systems for climate.

The array of climate services providers already in place, such as the Regional Climate Centers and State Climatologists, is essential in the delivery and use of climate information products. These centers provide operational information products used by public and private decision-makers. As models for transforming data into information and educating the public about the utility of climate information, these organizations are invaluable in the broad endeavor of transforming research into operations.

NOAA/private industry partnerships hold tremendous promise for innovative application of climate information. NOAA seeks to enhance our national competitiveness through optimized use of information. Industries such as weather derivatives, electricity production, agriculture, ranching, and fisheries could all achieve economic benefits with improved use of climate information. Climate observations and services will draw on the knowledge generated, and experience gathered, from association with other agencies, particularly through the U.S. Global Change Research Program. Research sponsored by the National Science Foundation and research satellites flown by National Aeronautics and Space Administration (NASA) are central to developing and improving climate services. Mission-driven research from the Department of Energy, such as its efforts on atmospheric radiation and carbon, is contributing important advances as well. Climate modeling partnerships with NASA and

the University Corporation for Atmospheric Research will be ventures to optimize common requirements such as hardware while retaining creative technical developments at individual institutions. Climate services to particular sectors such as agriculture, forestry, and water resources will be impossible without the participation of mission agencies like the Department of Agriculture, Department of Interior, and Environmental Protection Agency.

Global data sets require cooperation and partnerships with other nations. This is particularly true for climate data sets derived from satellite observations. Geostationary satellites are operated by the United States, Japan, India and the European Community and planned for China, as well as polar orbiting satellites operated by some of those nations. As in the United States, some of the satellite programs are experimental and some are operational; however, both provide important observations necessary for climate studies.



International partnerships are also critical to land and ocean observing programs. The United States has been a central participant in the Global Climate Observing System. For the newly deployed Argo ocean profiling system, international partners supply two-thirds of the instruments.

Finally, international partnerships like the Intergovernmental Panel on Climate Change (IPCC) will be important to a national climate service. The IPCC's conclusions on the state-of-the-science for climate change are some of the most authoritative in the world. NOAA will continue to participate in the IPCC process and other such assessments. A national climate service will be an important component of putting the IPCC scientific conclusions into a nation context.

6. Management Structure

Clearly, NOAA's Climate Observations and Services require contributions from several components of the organization, notably the Office of Oceanic and Atmospheric Research; the National Environmental Satellite, Data and Information Service; and the National Weather Service. Indeed, the unique existence of those capabilities and collection of relevant research and services implicitly answers the question, "Why NOAA?" Yet, that needed diversity raises perhaps the more significant challenge: "How will NOAA make the whole greater than the sum of its parts?" The points below reflect the credo and the mechanisms for making the program work.

Unique capabilities - defined contributions. NOAA's Climate Services defines specific responsibilities and builds upon the present capabilities and experience. For example, the National Weather Service provides the "official"

forecast and dissemination system as well as real-time monitoring; the National Environmental Satellite, Data and Information Service contributes data archive, dissemination, and climate monitoring; and the Office of Oceanic and Atmospheric Research brings research, monitoring, modeling, and assessment that builds a science-based knowledge of the climate system.

A constructive mix of research entities. The combination of the long-term, purposeful research of NOAA's internal, base-funded laboratories and an established university research program combines two strengths that are not duplicated elsewhere. The goal of steadily improving forecasts and predictions will benefit from this combination of long-term commitment and a variety of changing input.

Research/operations separateness and interaction. Based on lessons from the weather experience, separate but interacting research and operations are essential for the steady improvement of predictive capabilities and, at the same time, the meeting of a regular schedule of information services to the customer base.

Management and scientific advice. Success will depend critically on a central organizational unit for program focus and budget management, but one whose responsibility includes not only its own activities, but also the linking of the NOAA-wide participation to meet the program's goals. Overall program management requires three entities to address these needs: the Program Board, the Program Office, and the Science Advisory Board.

- *Program Board.* This group, appointed by the three Assistant Administrators, is the decision-making focal point (i.e., a Board of Directors) for the management of the diverse components of the program. This chaired group will establish, review, and assess the current and future priorities and budget elements of the program and the degree to which the goals of the program are being met. The Chair and the Board are accountable to the three Assistant Administrators and to NOAA Headquarters for the success of the program.

- *Program Office.* This office provides for staff support and implementation of Program Board actions. It is charged with coordination between the line offices of NOAA, presentation of NOAA climate issues to the Board, and interfacing with other agencies and outside advisory groups. The Program Office also prepares budget requests, submits budget recommendations for the Program Board, and monitors the execution of the Climate Observations and Services budget line.

- *Science Advisory Board.* Scientific advice to NOAA is coordinated through this group, and panels operating under this group will provide

expert advice to the Climate Observations and Services Program. These panels will evaluate the overall research and services of the NOAA climate endeavor, including the health of the climate observing system. The panels are composed of climate scientists and users of NOAA climate services.

7. Strategic Priorities

NOAA's Climate Observations and Services Program requires emphasis in four major areas. These are monitoring and observations, climate research, climate modeling, and the delivery of data, information, and knowledge about climate, broadly termed services, as illustrated in the tree figure. Each of these components of a comprehensive climate services program is critical to the overall success of the program. To help establish priorities within these areas, NOAA has relied upon the comprehensive set of review reports related to climate services, completed by National Research Council (NRC), the US Global Climate Research Program (USGCRP), the World Climate Research Program, and numerous national and international state-of-science assessments.

NOAA's climate services priorities are shown on the next page.

NOAA Climate Observations and Services Strategic Priorities

Monitoring and Observations

Deliver "benchmark" data sets and information, i.e., those needed to document key components of regional and global change and forcing.

Modernize and extend climate data records and observations.

Improve the effectiveness of new satellite-based observing systems for climate applications.

Provide for easy, affordable access to data and information.

Provide linkages to prediction and projection programs for testing and improvements of models.

Fulfill NOAA's mandate for the "protection of life and property."

Build and leverage off of NOAA's international and national partnerships.

Research

Expand the predictive capability for natural climate variability and links to weather.

Support programs that help to determine the sources and limits of precipitation predictability with special emphasis on North and Central America.

Focus on observations of water vapor, with a growing emphasis on processes studies and model diagnostics.

Develop and improve capability to project and track sources and sinks of atmospheric CO_2 concentrations using a combination of atmospheric and oceanic global observations, process-oriented field studies and modeling of the carbon cycle.

Determine through new studies and experiments the processes controlling the short-lived atmospheric constituents that have important radiative effects, e.g. aerosols and tropospheric ozone.

Modeling

Emphasize climate prediction on timescales of months to years.

Study climate variability and predictability on timescales of decades to centuries.

Address modeling uncertainties identified in national and international assessments of anthropogenic climate change.

Address modeling uncertainties identified in national and international ozone assessments.

Address modeling uncertainties identified in assessments the regional impact of climate variability and change.

Improve the linkages between the operational and research community modeling activities by means of a common modeling infrastructure and better access for researchers to computing facilities associated with operational activities.

Establish strong links between the modeling and observing programs.

Services

Define and carry out programs of regional and sector-based - e.g., agriculture, forests, water resources, energy distribution and use, transportation etc. - multiple-stress research and demonstration projects.

Coordinate the delivery of federal services through cooperation and collaboration with non-federal entities.

Develop public-private partnerships in delivery of climate services.

Develop improved assessment capabilities for integrating scientific knowledge into effective national and international decision support systems.

Provide easy access to NOAA data, products, and knowledge.

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